Metallic Environmentally Resistant Coating Rapid Innovation Initiative Under Extreme Space Environments. S. Rengifo[1], A. R. Gray[1], and W. Scott[1], [1]Marshall Space Flight Center, 4711 Apollo Street, Huntsville, Al 35808. (Contact: sara.m.rengifoalvarez@nasa.gov, annette.r.gray@nasa.gov)

Mission concepts such as JPL's Endurance-A campaign will utilize rovers such as Astrolab's FLEX concept to explore the lunar surface. For these types of systems, lightweight alloys such as aluminum (Al) and titanium (Ti) are often specified to minimize mass while maintaining structural integrity [1,2,3]. Such alloys, however, exhibit poor tribological response in the form of high friction and wear, especially in extreme space environments and with the additional presence of lunar regolith. This shortens the lifetimes of these systems which have a requirement to traverse 1,00km/year [2,3]. The MERCRII project is addressing the technology need of this and future rover missions by developing advanced wear- and radiation-resistant coatings for lightweight parts to extend the lifetime and sustainability of both lunar and Martian assets.

The MERCRII project focuses on the technology taxonomies of exploration destination systems, mission infrastructure, and sustainability and supportability to explore both new and existing coating technologies, including material formulations and application methods. Several material formulations were considered for their wear resistance and fracture toughness and the following were chosen for Phase I testing: Nickle Titanium (NiTi), Aluminum Oxide (AlO), and Ti64 with hBN at two and ten vol percent (Ti-2vol%hBN and Ti-10vol%hBN).

These coating materials were selected because they were anticipated to have high wear resistance along with other benefits. NiTi-based materials exhibit a high hardness to elastic modulus ratio, a property that has been shown to perform well in sliding applications. These materials also offer an extensive elastic deformation range, resulting in superior static indentation load capability [4]. Based upon laboratory static load tests performed at Glenn Research Center (GRC) [4], bearings made with NiTi alloys provide up to ten times higher tolerance to denting damage compared to conventional steel bearings. The BN-based coatings are expected to provide additional radiation shielding improvement because BN-nanomaterials are well known for their excellent mechanical and thermal properties, high impact resistance, low friction coefficient, chemical inertness, corrosion resistance, and good interfacial adhesion with Al and Ti metals.

Three application processes were used to apply these coating materials: atmospheric plasma spray (APS), vacuum plasma spray (VPS), and high-pressure cold spray [4,5,6]. For Phase I, NiTi was only applied by VPS, AlO was only applied by APS, Ti-10vol%hBN was applied with VPS and APS, and Ti-2vol%hBN was applied with all three techniques. The remaining combinations either did not adhere or showed excessive cracking or significantly low wear resistance during initial pathfinder testing.

In Phase I, the samples were subjected to thermal cycle and radiation environmental exposures and then underwent wear testing in an ambient environment in the presence of lunar regolith simulant. This testing provided lower fidelity simulated space environment to evaluate and compare the survival of these coatings. The coatings were down selected to three configurations for the next phase.

Phase II testing is currently underway for the three highest performing coatings: Ti-2vol%hBN APS, Ti-2vol%hBN VPS, and Ti-10vol%hBN VPS. The coatings were applied to both conventionally manufactured (CM) and additively manufactured (AM) substrates. The environmental exposures are being repeated, but the wear testing is being performed in a vacuum environment. Sand blast erosion testing and radiation shielding evaluation are also being performed on the samples. This phase increased the fidelity of the testing and provided many additional data points for the performance of these coatings.

The highest performing coating, Ti-2vol%hBN VPS, was selected for Phase III to demonstrate effectiveness in an even higher fidelity wear environment. The coating will be applied to three mechanisms of action: joint, torsional, and sliding, which will be fabricated from both CM and AM aluminum and titanium. These mechanisms of action encompass commonly utilized mechanisms and will enable this technology development effort to create optimized advanced wear coating options that will protect an array of future mechanisms for the Moon, Mars, and beyond.

This technology could be applied to any mobility systems, including EVA and robots (rovers, wheels, motors, bearings, hinges, chassis, actuators, etc.) such as for the Endurance-A mission. The coatings are being developed and tested to extend the service life of mechanisms operating in dusty lunar environments.

References:

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